TELEMATIC SCHOOLS PROJECT

2023 SUBJECT WORKBOOK
Grade 12

PHYSICAL SCIENCES

A joint initiative between the Western Cape Education Department and Stellenbosch University.

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BROADCAST SESSIONS

GRADE 12 **PHYSICAL SCIENCES**

Session	Date	Time	Topic
1	**25/01/2023**	**15h00-16h00**	**Momentum**
2	17/04/2023	16h00-17h00	Doppler effect
3	**02/08/2023**	**16h00-17h00**	**Photoelectric effect**

SESSION 1 | MOMENTUM

Momentum

- Define *momentum* as the product of an object's mass and its velocity.
- Describe the *linear momentum* of an object as a vector quantity with the same direction as the velocity of the object.
- Calculate the momentum of a moving object using p = mv.
- Describe the vector nature of momentum and illustrate it with some simple examples.
- Draw vector diagrams to illustrate the relationship between the initial momentum, the final momentum and the change in momentum for each of the cases above.

Newton's second law of motion in terms of momentum

- State Newton's second law of motion in terms of momentum: The net (or resultant) force acting on an object is equal to the rate of change of momentum of the object in the direction of the net force.
- Express Newton's second law of motion in symbols: $F_{net} = \frac{\Delta p}{\Delta t}$
- Explain the relationship between net force and change in momentum for a variety of motions.
- Calculate the change in momentum when a resultant/net force acts on an object and its velocity:
  - Increases in the direction of motion, e.g. 2nd stage rocket engine fires
  - Decreases, e.g. brakes are applied
  - Reverses its direction of motion, e.g. a soccer ball kicked back in the direction it came from

SESSION 1 | MOMENTUM

Impulse

- Define *impulse* as the product of the resultant/net force acting on an object and the time the net force acts on the object.
- Use the impulse-momentum theorem, $F_{net}\Delta t = m\Delta v$, to calculate the resultant/net force exerted, the time for which the net force is applied and the change in momentum for a variety of situations involving the motion of an object in one dimension.
- Explain how the concept of impulse applies to safety considerations in everyday life, e.g. airbags, seatbelts and arrestor beds.

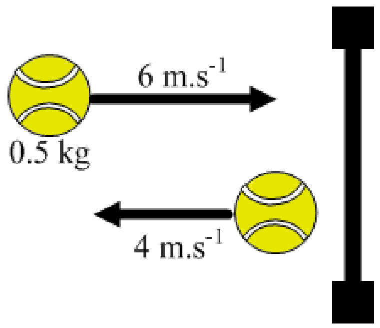
Conservation of momentum and elastic and inelastic collisions

- Explain what is meant by a *system* (in Physics).
- Explain (when working with systems) what is meant by *internal* and *external forces*.
- Explain what is meant by *an isolated system* (in Physics) i.e. a system on which the net external force is zero.

  An isolated system excludes external forces that originate outside the colliding bodies, e.g. friction. Only internal forces, e.g. contact forces between the colliding objects, are considered.
- State the principle of conservation of linear momentum: The total linear momentum of an isolated system remains constant (is conserved).
- Apply the conservation of momentum to the collision of two objects moving in one dimension (along a straight line) with the aid of an appropriate sign convention.

Distinguish between *elastic collisions* and *inelastic collisions* by calculation

Example: A ball, mass 0.5 kg, initially moves to the right at 6 m.s^{-1} and bounces against a vertical wall. The ball leaves the wall with a velocity of 4 m.s^{-1}as indicated in the sketch. Ignore the effects of gravity on the ball. Calculate the change in momentum of the ball.



Choosing towards the right (towards the wall) as positive, the solution is as follows:

$\Delta p = p_f - p_i$

$= mv_f - mv_i$

$= 0,5(-4-6)$

$= -5$ kg.m.s^{-1}

The chance in momentum is 5 kg.m.s^{-1} to the left or (away from the wall)

SESSION 1 | MOMENTUM

Conservation of linear momentum states: *The total linear momentum of an isolated system remains constant* ***OR*** *'In an isolated system the total momentum before a collision (or explosion) is equal to the total momentum after the collision (or explosion)'.*

$$\sum p_{\text{before}} = \sum p_{\text{after}}$$

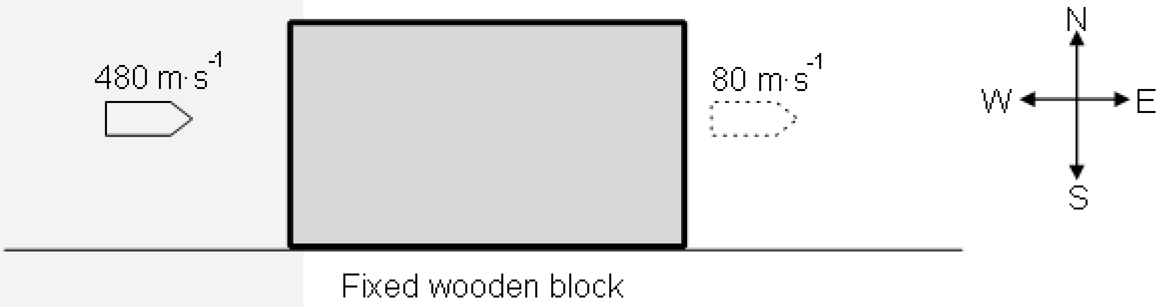
$$p_{\text{A(before)}} + p_{\text{B(before)}} = p_{\text{A(after)}} + p_{\text{B(after)}}$$

$$m_A v_{iA} + m_B v_{iB} + \ldots = m_A v_{fA} + m_B v_{fB} + \ldots$$

A bullet moves east at a velocity of 480 m·s^{-1}. It hits a wooden block that is fixed to the floor. The bullet takes 0,01 s to move through the stationary block and emerges from the block at a velocity of 80 m·s^{-1} east. See the diagram below.

Ignore the effects of air resistance.

Consider the block-bullet system as an isolated system.



1.1 Explain what is meant by an isolated system as used in Physics. (2)

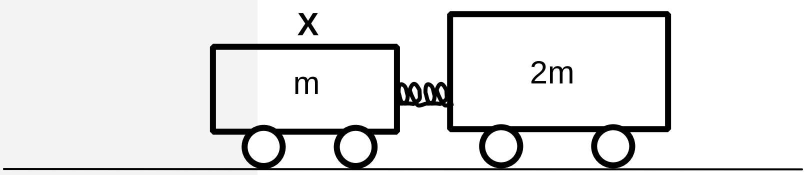
The magnitude of the momentum of the bullet before it enters the block is 24 kg·m·s-1.

1.2 Calculate the:

1.2.1 Mass of the bullet (3)

1.2.2 Average net force exerted by the wooden block on the bullet (5)

2. Two trolleys, X and Y, of masses m and 2m respectively, are held together by a compressed spring between them. Initially they are stationary on a horizontal floor, as shown below. Ignore the effects of friction.



The spring is now released and falls to the floor while the trolleys move apart.

The magnitude of the MOMENTUM of trolley X while it moves away is …

A zero.

B half the magnitude of the momentum of trolley Y.

C twice the magnitude of the momentum of trolley Y.

D the same as the magnitude of the momentum of trolley Y.

1.3 Two cars, P and Q, moving in a straight line, have the same momentum.

The kinetic energy of Q is greater than the kinetic energy of P.

Which ONE of the following statements regarding the cars is CORRECT?

A Q has a smaller mass than P.

B Q has the same mass as P.

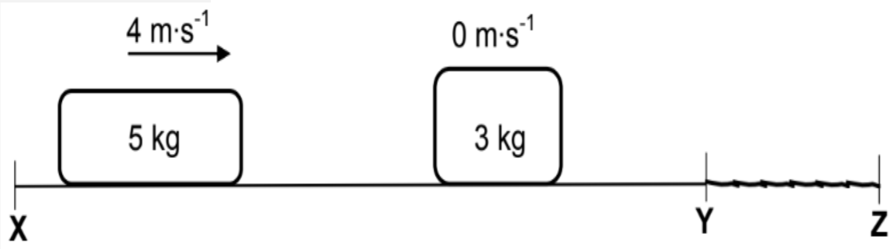
C Q is moving slower than P.

D Q is moving at the same speed as P.

1.4 The diagram below shows two sections, XY and YZ, of a horizontal, flat surface. Section XY is smooth, while section YZ is rough.

A 5 kg block, moving with a velocity of 4 $m \cdot s^{-1}$ to the right, collides head-on with a stationary 3 kg block. After the collision, the two blocks stick together and move to the right, past point Y.

The combined blocks travel for 0,3 s from point Y before coming to a stop at point Z.



1.5 State the principle of conservation of linear momentum in words. (2)

1.6 Calculate the magnitude of the:

1.6.1 Velocity of the combined blocks at point Y (4)

1.6.2 Net force acting on the combined blocks when they move through section YZ (4)

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SESSION 2 | DOPPLER

- **Doppler Effect (relative motion between source and observer)**
- **With sound and ultrasound**
- State the Doppler effect as the change in frequency (or pitch) of the sound detected by a listener because the sound source and the listener have different velocities relative to the medium of sound propagation.
- Explain (using appropriate illustrations) the change in pitch observed when a source moves toward or away from a listener.
- Solve problems using the equation $f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ when EITHER the source OR the listener is moving.
- State applications of the Doppler effect.

- **With light – red shifts in the universe (evidence for the expanding universe)**
- Explain *red shifts*.

Use the Doppler effect to explain why we conclude that the universe is expanding.

SESSION 2 | DOPPLER

Key points to consider when studying this topic:

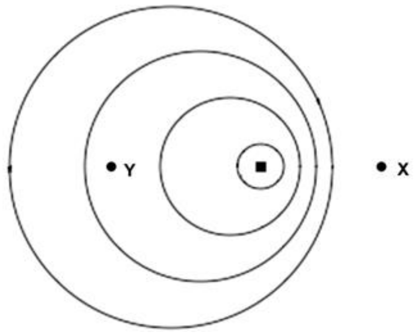
- The Doppler Effect is the change in frequency (or pitch) of the sound detected by a listener because the sound source and the listener have different velocities relative to the medium of sound propagation. When the pitch is high, the frequency is high and vice versa. When a source of sound is moving towards a stationary listener the pitch will be high and when it moves away from the stationary listener the pitch will be low.
- Remember that either the source of sound or the listener observing the sound will move and not both at the same time.
- You should be able to perform calculations based on the formulae $f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ and v = fλ or T = $\frac{1}{f}$.
- The speed of sound in air (v) is 340 $m.s^{-1}$ unless stated otherwise.
- Highlight and study definitions from the examination guidelines (page 11).
- Common mistakes made: Learners do not state the definition of the Doppler Effect as per examination guidelines, learners do not convert to SI units.
- When performing Doppler Effect calculations, it is important to write the correct formula from the datasheet as is and only manipulate the formula afterwards. Solve the problem by determining the unknown value. Sometimes it could be expected to solve two equations simultaneously to determine the answer.

Remember when interpreting graphs of frequency versus time that where there is a change in the curve that is when the apparent change in frequency occurs.

SESSION 2 | DOPPLER

2. An ambulance is traveling towards a hospital at a constant velocity of 30 $m\cdot s^{-1}$. The siren of the ambulance produces sound of frequency 400 Hz. Take the speed of sound in air as 340 $m\cdot s^{-1}$.

The diagram below shows the wave fronts of the sound produced from the siren as a result of this motion.



2.1 At which side of the diagram, X or Y, is the hospital situated? (1)

2.2 Explain the answer to QUESTION 2.1. (3)

2.3 Calculate the frequency of the sound of the siren heard by a person standing at the hospital. (5)

2.4 Name the phenomenon that describes the apparent change in frequency detected by the observer. (1)

2.5 A nurse is sitting next to the driver in the passenger seat of the ambulance as it approaches the hospital. Calculate the wavelength of the sound heard by the nurse. (3)

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SESSION 2 | DOPPLER

2.6 A police car, with its siren on, is travelling at a constant speed TOWARDS a stationary sound detector. The siren emits sound waves of frequency f and speed v.

Which ONE of the following combinations best describes the frequency and speed of the detected sound waves?

	FREQUENCY	SPEED
A	Less than f	v
B	Less than f	Less than v
C	Greater than f	Less than v
D	Greater than f	v

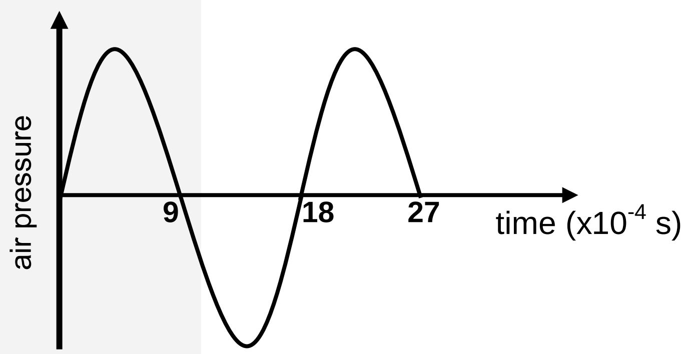
SESSION 2 | DOPPLER

2.7 The siren of a police car, which is travelling at a constant speed along a straight horizontal road, emits sound waves of constant frequency. Detector **P** is placed inside the police car and detector **Q** is placed next to the road at a certain distance away from the car. The two detectors record the changes in the air pressure readings caused by the sound waves emitted by the siren as a function of time.

The graphs below were obtained from the recorded results.

GRAPH A: AIR PRESSURE VS TIME RECORDED BY DETECTOR P IN THE CAR

GRAPH B: AIR PRESSURE VS TIME RECORDED BY DETECTOR Q NEXT TO THE ROAD



SESSION 2 | DOPPLER

2.8 Different patterns are shown above for the same sound wave emitted by the siren. What phenomenon is illustrated by the two detectors showing the different patterns?
The police car is moving AWAY from detector **Q**.

2.8.1 Use the graphs and give a reason why it can be confirmed that the police car is moving away from detector **Q**. (1)

2.8.2 Calculate the frequency of the sound waves recorded by detector **P**. (3)

2.8.3 Use the information in the graphs to calculate the speed of the police car. Take the speed of sound in air as 340 $m \cdot s^{-1}$. (6)

[11]

SESSION 3 | PHOTOELECTRIC EFFECT

Photo-electric effect

- Describe the *photoelectric effect* as the process whereby electrons are ejected from a metal surface when light of suitable frequency is incident on that surface.
- State the significance of the photoelectric effect.
- Define *threshold frequency*, f_o, as the minimum frequency of light needed to emit electrons from a certain metal surface.
- Define *work function*, W_o, as the minimum energy that an electron in the metal needs to be emitted from the metal surface.
- Perform calculations using the photoelectric equation:

  $E = W_o + E_{k(max)}$, where $E = hf$ and $W_o = hf_o$ and $E_{k(max)} = ½ mv$

- Explain the effect of intensity and frequency on the photoelectric effect.
- State that the photoelectric effect demonstrates the particle nature of light.

Emission and absorption spectra

- Explain *the formation of atomic spectra* by referring to energy transition.
- Explain the difference between *atomic absorption* and atomic *emission spectra*.

  An atomic absorption spectrum is formed when certain frequencies of electromagnetic radiation passing through a substance is absorbed.

  For example, when light passes through a cold gas, atoms in the gas absorb characteristic frequencies of the light and the spectrum observed is a continuous spectrum with dark lines where characteristic frequencies of light were removed. The frequencies of the absorption lines are unique to the type of atoms in the gas.

  An atomic emission spectrum is formed when certain frequencies of electromagnetic radiation are emitted due to an atom making a transition from a higher energy state to a lower energy state.

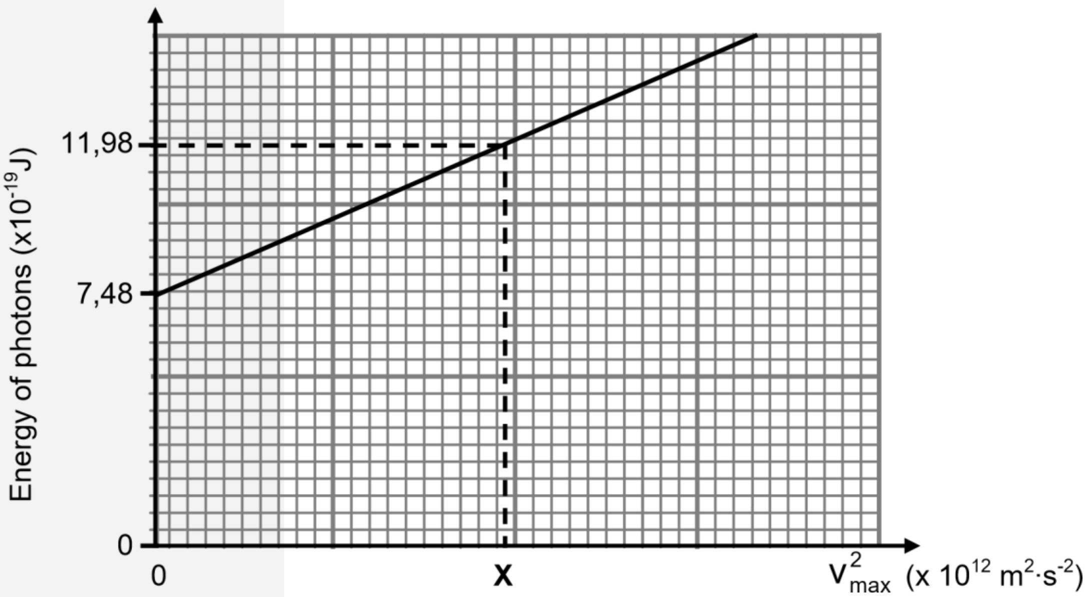
For example, atoms in a hot gas emit light at characteristic frequencies. The spectrum observed is a line spectrum with only a few coloured lines of frequencies unique to the type of atom that is producing the emission lines.

SESSION 3 | PHOTOELECTRIC EFFECT

During an experiment, light of different frequencies is radiated onto a silver cathode of a photocell and the corresponding maximum speed of the ejected photoelectrons are measured.

A graph of the energy of the incident photons versus the square of the maximum speed of the ejected photoelectrons is shown below.

Graph of energy of photons versus square of maximum speed of photoelectrons



3.1 Define the term *photoelectric effect*. (2)

Use the graph to answer the following questions.

3.2 Write down the value of the work function of silver.

Use a relevant equation to justify the answer. (3)

3.3 Which physical quantity can be determined from the gradient of the graph? (1)

3.4 Calculate the value of **X** as shown on the graph. (5)

The experiment above is now repeated using light of higher intensity.

3.5 How will EACH of the following be affected? Choose from INCREASES, DECREASES or REMAINS THE SAME.

3.5.1 The gradient of the graph (1)

3.5.2 The number of photoelectrons emitted per unit time (1)

SESSION 3 | PHOTOELECTRIC EFFECT

3.6 Consider the statements below regarding the photoelectric effect.
The photoelectric effect proves that …

(i) light energy is quantised.

(i) light has a particle nature.

(i) light has a wave nature.

Which of the statements above is/are CORRECT?

A. (i) only

B. (ii) only

C. (i) and (ii) only

D. (i) and (iii) only (2)

3.7 A group of students investigates the relationship between the work function of different metals and the maximum kinetic energy of the ejected electrons when the metals are irradiated with light
of suitable frequency.

3.7.1 Define term work function.

During the investigation ultraviolet rays of wavelength 2×10^{-8} m are allowed to fall on different metal plates. The corresponding maximum kinetic energies of ejected electrons are measured.
The data obtained is displayed in the table below.

METAL PLATE USED	MAXIMUM KINETIC ENERGY ($E_{k(max)}$) ($\times 10^{-18}$ J)
Lead	9,28
Potassium	9,58
Silver	9,19

3.8 Write down the dependent variable for this investigation. (1)

3.9 Write down ONE control variable for this investigation. (1)

3.10 Using the information in the table, and without any calculation, identify the metal with the largest work function.

Explain the answer. (3)

3.11 Use information in the table to calculate the work function of potassium. (4)

3.12 State how an increase in the intensity of the ultraviolet light affects the maximum kinetic energy of the photoelectrons. Choose from: INCREASES, DECREASES, REMAINS THE SAME.

Explain the answer. (3)

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